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Sorting device.

The present invention is situated in the field of sorting devices.

In particular, it relates to sorting devices which allow to process a large product flow, in such a manner that sorting can be applied on an industrial level.

An important application for such sorting devices can be found in the food industry, for example, for sorting not-pertaining products out of certain foodstuff, in particular leaves, twigs and pieces of waste such as wood, plastic, stones, and so on. However, other applications, whether or not in the food industry, are not excluded.

Known sorting devices comprise a transport system bringing products to be sorted to an inspection unit. When these products to be sorted are at the height of the inspection unit, they are inspected, mostly by means of electromagnetic radiation, for example, visible or invisible light, and in consideration of the obtained results a decision is made concerning the acceptability or non-acceptability of the products. Unacceptable products, these are undesired elements or products of a lower quality, are taken out of the product flow by means of a rejection unit, for example, an apparatus working on the basis of compressed air, and form, for example, a flow of rejected products.

For inspection, for example, light is sent to the products to be sorted which, for example, is chosen such that acceptable and unacceptable products interact with the light in a different manner. Hereby, the reflected

light then is measured and, by means of this measured reflected light, the location of unacceptable products, which have to be removed from the product flow, is determined.

It is also known that in such sorting devices, it can not be worked exclusively with reflected light. For selection, however, any form of interaction between the electromagnetic radiation and the product, whereby as well reflected, transmitted, emitted and/or, in respect to wavelength and/or polarisation, transformed electromagnetic radiation can be received or measured, can be applied for forming a signal from which a decision can be made in respect to the acceptability or non-acceptability of the products to be sorted.

It is also known to apply two or more light sources during the same sorting procedure, for example, by means of light of different wavelengths. In order to realize this, as usual in sorting devices, use can be made of free space optics with classical optical elements, such as dichroic bundle splitters and similar.

Hereby, it is necessary that, in order to perform precise measurements, the different light bundles are aligned to one single light ray, such that always information of the same point of the inspection line is obtained. With a bad alignment, the information of the different light bundles will no longer come from one and the same point, and the risk arises that wrong decisions will be taken during selecting, as a result of which the performance of the sorting device strongly diminishes.

One of the problems when using free space optics in sorting devices whereby several light bundles are applied simultaneously, however, is the stability thereof. The

least deviation in the installation of the applied optical elements has as a consequence that the different light bundles are no longer perfectly aligned, which leads to the aforementioned disadvantage.

This disadvantageous effect is still increased in that such sorting devices mostly are strongly subjected to temperature differences and/or vibrations.

Sorting devices actually are applied in the most extreme production conditions, ranging from, for example, deep-freeze temperatures (-25°C) to the hot conditions in, for example, the tobacco-processing industry (up to +40°C). The classical optical elements are fitted in mechanical holders, and temperature changes, thus, may cause undesired deformations.

Moreover, a sorting device mostly is subjected to vibrations in that, for example, use is made of vibration tables for directing the products in a steady manner through the sorting device.

It is obvious that the aforementioned deviations may become manifest only after a certain period of time, in such a manner that an originally perfect alignment does not offer a guarantee for an optimal performance after a period of time.

It is a first aim of the present invention to offer a solution for the above-mentioned problem.

According to a first aspect of the invention, it thus relates to a sorting device, provided with an inspection unit where products to be sorted are inspected on their acceptability, a transport system feeding a product flow of products to be sorted to the inspection unit, and a

rejection unit taking unacceptable products out of the product flow, with as a characteristic that the inspection unit, at the sending side, is provided with at least two sources for generating electromagnetic radiation, more particularly light, as well as of means making use of waveguide technology for having the electromagnetic radiation meet the products to be sorted, whereby these means function as an alignment system for the radiation originating from the aforementioned sources.

By making use of optical waveguide technology in sorting devices with two sources and by directing the radiation, more particularly the light, along the same waveguides to the products, the radiation beams, more particularly light beams, are aligned automatically and mutual deviations at the location of the products are excluded. Apart from the fact that mutual deviations among the radiation beams are entirely excluded, in general also a better guidance of the radiation beams is obtained, such that also deviations occuring in the known embodiments which are based exclusively on the use of free space optics, now are reduced or excluded.

At the sending side, this is there where electromagnetic radiation originating from a radiation source is directed to the products to be sorted, a sorting device according to the invention thus is provided with two or more light sources. The light, originating from each of these light sources, can be coupled into optical waveguides, by means of coupling-in optics, whereby at least one optical waveguide per light source is provided. Moreover, a combining unit can be provided for combining light from these optical waveguides in one or more waveguides, so-called outgoing waveguides, which each contain a certain quantity of light originating from one or more light sources. Focussing optics provide for that the light beam

exiting the waveguide(s) is focussed onto the products to be sorted. The combining unit, however, does not have to be coupled to the sources by means of waveguides, but also may comprise them. The outgoing waveguides with their focussing optics can be brought to one and the same optical unit in order to illuminate, for example, the product along different sides, or to several optical units or sorting devices.

According to a preferred embodiment, the light sources are laser sources, but also LEDs or other light sources in general can be used with the technology according to the invention.

Furthermore, it is also known that in the sorting devices known up to the present, use is made of a lens or lens system for creating an image of the light dispersed by the product. This image can be partially diffuse, and different for each product. By means of placing diaphragms into the image plane, it can be determined how each products disperses the light, which, [illegible] certain applications, can be used for deducing selecti[illegible] criteria therefrom. If information over different parts of the dispersed spot on the product is desired, according to the technology known up to the present the received light first is split up into various similar beams, for example, by means of semi-translucent mirrors, and in each beam, a different diaphragm is placed in order to get thereby information in respect to the different parts of the image. Such splitting of the light beam has as a consequence that each time a quantity of light is lost, as a result of which the signal-to-noise ratio diminishes, which leads to a diminishing detection performance. Moreover, for each diaphragm each time a new alignment has to be performed, which remains time-consuming, expensive and not always guaranteed after a

certain period of time.

It is a second aim of the present invention to offer a solution for this problem.

According to this second aim, a sorting device is intended with which, contrary to the use of the afore-mentioned classical diaphrams, a selection can be performed in a more efficient way.

According to a second aspect of the invention, it thus also relates to a sorting device, provided with an inspection unit where products to be sorted are inspected on their acceptability on the basis of a selection which is performed in function of the electromagnetic radiation reflected and/or transmitted and/or emitted and/or transformed by these products, a transport system feeding a product flow of products to be sorted to the inspection unit, and a rejection unit taking unacceptable products out of the product flow, with as a characteristic that the inspection unit, at the detection side, is provided with means which make use of a waveguide selection system for receiving the electromagnetic radiation reflected and/or transmitted and/or emitted and/or transformed by the products to be sorted.

By making use of a waveguide selection system, information relating to the dispersion pattern of the radiation, more particularly the light, can be obtained in a simple manner, without the necessity of splitting the entire radiation beam.

The applied components preferably are connectorized, which contributes to the stability and the modularity of the system.

At the detection side, this is where the electromagnetic radiation reflected, transmitted, emitted and/or transformed by the products to be sorted is sent to one or several detectors, preferably then use is made of several optical waveguides which are combined to a bundle. Such bundle can be built up of one or several, preferably substantially concentric bundles. According to a further preferred embodiment, these parts, more particularly the substantially concentric bundles, are separated from each other by means, for example, a ring, in order to avoid cross-coupling between the bundles. Each of the parts, more particularly of the substantially concentric bundles, can be separately led to detectors or splitting optics, where the electromagnetic radiation reflected, transmitted, emitted and/or transformed by the products to be sorted is processed, in order to be able to make a decision in respect to the acceptability of the products to be sorted.

The waveguide technology thus can be used at the sending side or at the detection side, whereby this technology, according to a first aspect of the invention, is applied as an alignment system at the sending side and, according to a second aspect of the invention, is applied as a waveguide selection system at the detection side. This first and second aspects, in function of the desired application, either or not can be combined in one and the same sorting device. It is noted that the use of waveguide technology in sorting devices is known in itself from documents WO 98/19800, NL 8720394, US 5.729.473 and US 5.351.117, however, none of the devices described in said documents applies this waveguide technology as an alignment system or as a waveguide selection system, such that the intended advantages therefore are not achieved by means of the aforementioned systems.

According to a third aspect of the invention, it relates to a sorting device, provided with an inspection unit where products to be sorted are inspected on their acceptability, a transport system feeding a product flow of the products to be sorted to the inspection unit, and a rejection unit taking unacceptable products out of the product flow, with as a characteristic that the inspection unit is provided with a bundle of waveguides and/or with waveguides which is, respectively are common for the sending part and the detection part of the inspection unit. In this manner, deviations which possibly occur, such as so-called drift between the signals of the sending side and the detection side, can be excluded or minimized. This third aspect of the invention either or not can be applied in one and the same sorting device in combination with one or both of the aforementioned two aspects.

According to the third aspect, the sending part can make use of certain waveguides, whereas the detection part makes use of other waveguides from the same bundle, such that the bundle is common, in other words, exiting and returning light passes through different optical fibers, but through one and the same bundle. The sending part may also make use of certain waveguides, whereas the radiation of the detection part is returned through one or more of the same waveguides, in other words, exiting and returning light passes through the same optical fibers.

Other preferred characteristics are described in the respective subclaims.

With the intention of better showing the characteristics of the invention, hereafter, as examples without any limitative character, several preferred forms of

embodiment are described, with reference to the accompanying drawings, wherein:

figure 1 schematically represents a sorting device;

figure 2 schematically represents a part of a known embodiment of a sorting device;

figure 3 represents how the light behaves in the embodiment of figure 2;

figure 4 shows a basic scheme for combining and focussing two light sources in two waveguides, this according to the present invention;

figure 5 represents the principle of coupling-in in an optical waveguide with the assistance of connectorized opto-electronic components;

figure 6 is an example of an achromatic focussing unit with one optical element;

figure 7 schematically represents a system with optical waveguides at the sending side of a sorting device;

figure 8 schematically represents a system with optical waveguides at the detection side of a sorting device;

figure 9 is a schematic representation of the geometry of a receiving waveguide bundle according to a preferred embodiment, such according to, for example, the cross-section indicated by line IX-IX in figure 8;

figure 10 shows another schematic representation, comparable to those of figure 9, however, for a variant and in perspective.

Similar parts in the different figures have been given the same reference numbers.

Figure 1 schematically represents the general construction and the functioning principle of a sorting device

which are valid for the known embodiments as well as for the embodiment described hereafter. This sorting device 1 hereby substantially consists of an inspection unit 2 where products 3 to be sorted are inspected on their acceptability, a transport system 4 feeding a product flow 5 of products 3 to be sorted to the inspection unit 2, and a rejection unit 6 removing unacceptable products 3A out of the product flow 5.

In the represented example, the transport system 4 is schematically represented as a transport conveyor 7 with which the products 3 are supplied in the form of a wide, however, thin product flow 5 and with which the products 3 are directed in free descent through an inspection zone 8, where the inspection unit 2 is active.

The inspection unit 2 consists of a combination of optical means, with which radiation, more particularly light, is shone onto the products 3 in the inspection zone 8 and with which the radiation re-collected as a result thereof, the light re-collected as a result thereof, respectively, is received and is applied in order to perform a selection, more particularly, to verify whether each respective product 3 has to remain in the product flow 5 or not. Preferably, hereby use is made of a light beam 9 which rapidly moves in the width, which continuously scans the passing products 3. The radiation emitted by each product 3 is immediately observed and interpreted, and if it is determined that a certain product 3A has to be removed from the product flow 5, the rejection unit 6 is controlled in a suitable manner.

As represented in figure 1, this rejection unit 6 may consist, for example, of a series of separately controllable blow nozzles 10 which are directed onto the product flow 5. In consideration of the fact that it can

be derived from the direction angle of the light beam 9 where the product 3A to be removed is situated, the blow nozzle 10 corresponding according to the width direction can be switched on at the suitable moment, as a result of which at least the product 3A concerned is blown off the product flow 5 in order to be collected, for example, in a waste receptacle 11 or such.

As schematically represented in figure 2, it is known that, for performing the inspection, use can be made of two light sources 12 and 13 which each generate a light bundle 14, 15 respectively, which together form the light beam 9. Hereby, the light in question can be of different wavelength in order to create different effects which can be necessary for performing an efficient selection.

As explained in the introduction, the two light beams 14 and 15 in the known embodiments are brought together by means of classical free space optics, whereby use is made of, for example, a semi-translucent mirror 16. As is visible in figure 2, it is obvious that the least deviation in the position of this mirror 16 leads to that the light beam 15 no longer coincides with the light beam 14. This has as a consequence that, as represented in figure 3, situations occur whereby one light beam 14 meets the product 3, whereas the other light beam 15 shines next to it, as a result of which simultaneously information is obtained of two totally different points, which may lead to a faulty interpretation.

According to a first aspect of the invention, this is remedied in the manner described hereafter.

As represented in figure 4, according to the invention light L1-L2 originating from two or more light sources 17-18, either or not with a different wavelength or

wavelength spectrum, is coupled into optical waveguides 19-20 by means of coupling-in optics 21-22. These coupling-in optics 21-22 may, for example, consist of gradient index (GRIN) lenses or achromatic lenses.

The light from these optical waveguides 19-20 is combined, by means of a combining unit 23, in one or several waveguides 24-25 which each comprise light L1, L2 respectively, of the above-mentioned light sources 17-18. The combining unit 23 can consist either of a system with dichroic elements or of elements which make use of fused optical waveguide technology or of other elements leading to the same effect.

Figure 5 illustrates in a general manner the principle of the coupling-in of light originating from a laser source 26 into a waveguide 27, by means of connectorized opto-electronic components 28. This form of coupling-in can be applied, for instance, for the aforementioned coupling-in optics 21-22.

The light beams in the waveguides 24-25 are focussed onto the products 3-3A to be sorted by means of focussing units 29-30. The optics in these focussing units 29-30 preferably provides for that light of different wavelengths produces one and the same spot size at the height of the product 3-3A to be sorted. The optics in the focussing units 29-30 may consist of different components and/or lenses in order to obtain a flexible installation in respect to focus distance and required spot diameter on the product 3-3A to be sorted.

Figure 6 represents an example of an achromatic focussing unit, in this case the aforementioned unit 29. Light exiting a fiber end of the waveguide, for example, 24, meets an achromatic focussing unit 29 provided with, in

this case, only one lens 31. This lens 31 focusses the light onto the product 3-3A to be sorted.

Such method at all times guarantees a perfect alignment of the different light beams, wavelengths, respectively, as a result of which the stability of the sorting machine 1 is strongly enhanced. The use of waveguides 21-22-24-25 moreover makes it possible to place the light sources 17-18 at a distance of the actual inspection unit 2, as a consequence whereof a more efficient cooling is made possible. This renders the sorting device 1 more stable in respect to temperature influences.

A complete system of the sending side of a sorting device 1 according to the invention is illustrated in figure 7. Hereby, light L1-L2-L3 originating from a number of light sources, in this case, three, 17-18-19 respectively, for example, with respective wavelengths G1-G2-G3, is coupled, by means of coupling-in optics 21-22-33, into optical waveguides 19-20-34. The light sources 17-18-32 preferably are Peltier-cooled semiconductor lasers and/or solid matter lasers having superior characteristics in respect to temperature stability, mode stability, pointing stability and so on, this contrary to, for example, gas lasers. A combining unit 23, in this case a nxm combining unit, this means, with n incoming and m outgoing waveguides (in this case, each time three, but these values may vary), brings the light from the light sources 17-18-32 together in one or more waveguides, in this case 24-25-35, which then comprise a certain quantity of light from the light sources 17-18-32, for example, each a certain percentage of the light L1, each a certain percentage of the light L2, as well as each a certain percentage of the light L3. These waveguides 24-25-35 guide the light to a focussing unit, 29-30-36, respectively, which preferably provide for that each kind

of light, L1-L2-L3, respectively, renders the same spot size at the height of the products 3-3A to be sorted. The light is guided towards the products 3-3A to be sorted by means of a mirror 37 with a circular opening, and a rotating polygon 38 which, in a known manner, provides for that the light scans the products 3-3A to be sorted.

It is noted that the waveguides 19-20-34 and 24-25-35 can be made of singular as well as of multiple guides, in other words, can comprise one or more optical fibers each.

Also at the detection side, the stability of the optics of a sorting device 1 can be enhanced by making use of optical waveguide technology. Moreover, thereby the alignment costs are limited.

According to the aforementioned second aspect of the invention, by means of the waveguide technology also a selection possibility is provided which allows a selection analogous to the one by means of diaphragms, but, as already explained in the introduction, in a more efficient and efficacious manner.

As represented in figure 8, according to the present invention the light 39 reflected, transmitted or emitted and/or transmitted by the products 3-3A to be sorted is received by means of a bundle 40 of optical waveguides. This bundle 40 is composed of separate optical waveguides, in this case, 41 and 42, respectively, where the light 39 originating from the products 3-3A to be sorted is coupled in by means of a lens system 43. The ingoing end of the bundle 40 is situated in the image plane 44 of the lens system 43.

The bundle 40 consists of several parts 45-46, more

particularly partial bundles, which, in the represented example, as can be seen in figure 9, are made as two concentric bundles, an inner bundle in the center and an outer bundle at the exterior, respectively, which also are indicated with reference numbers 45 and 46, respectively. It is obvious that these partial bundles not necessarily have to consist of concentric parts and, in function of the application, may also be build up in another manner.

Each of the bundles 45-46 consists of a part of the separate optical waveguides 41-42 forming the entire bundle 40 and preferably are separated from each other by means, such as a ring 47, in order to prevent cross-coupling between the inner bundle 45 and the outer bundle 46.

As represented in figure 8, the entire bundle of optical waveguides 40 is split into two separate bundles 48-49, respectively formed by the waveguides 41-42 defining the inner bundle 45 and the outer bundle 46 at the ingoing end. These bundles 48-49 are directed to detectors 50 and/or splitting optics 51. Instead of the splitting optics 51 and a lens 52, use may also be made of a component having several outgoing waveguides.

Although this is not strictly necessary, preferably optical waveguides 41-42 are used with a large core diameter/mantle diameter ratio, for example 40 micrometer/50 micrometer, and/or a high numerical aperture (NA) for rendering the light capacity as efficient as possible.

By means of the geometry described hereabove, it is possible, by means of a good choice of the bundle geometry, to collect, apart from the total light 39 reflected, transmitted or emitted and/or transformed by

the products 3-3A to be sorted, also image information of the light dispersed on the products 3-3A to be sorted. This contributes to an increase of the differenciating capacity between acceptable products 3 and unacceptable products 3A. If the bundle 49 corresponding to the outer bundle 46 namely is positioned in the image plane of a lens 52, an image shall be formed with light contents equal or almost equal to the light contents of the image at the location of the ingoing end of the outer bundle 46. When the product to be sorted 3-3A disperses the light very strongly, the quantity of light 39, originating from the product 3 or 3A and received in the outer bundle 46, will be relatively large. When, on the contrary, the product 3-3A practically does not disperse any light, the quantity of light 39 originating from the product 3-3A and collected in the outer bundle 46 will be rather small. On the basis of the quantity of light collected in the outer bundle 46, a sorting can be performed or optimized. It is obvious that in this manner, a selection is obtained analogous as with the use of diaphragms, however, with, amongst others, the additional advantages mentioned in the introduction.

It is possible to obtain still more refined information in respect to the dispersion by using more than two concentric bundles of optical waveguides, for example, three or more, each preferably, but not necessarily, separated from each other by means, such as a ring, in order to avoid cross-coupling between the different bundles. If, for example, three parts, for example, concentric bundles 45-46-53 are used for collecting the light 39, for example, such as represented in figure 10, the waveguides used for collecting the light 39, behind the ingoing end, for example, in the proximity of the outgoing end, split up into three separate bundles 48-49-54 which respectively correspond to the aforementioned

inner bundle 45, intermediate bundle 53 and outer bundle 46 which each are directed to detectors and/or splitting optics. Other geometries of the bundles are also possible. It is also possible to apply several bundles which are placed after the splitting optics 55 represented in figure 8, for example by providing an additional bundle 56 with parts 57-58 in order to obtain, for example, wavelength and/or polarisation information of the products to be sorted. It is also possible to use only a single waveguide which then can be directed to detectors, splitting optics.

The light 39 originating from the product 3-3A to be sorted which is received by the different partial bundles, for example, the aforementioned inner and outer bundles 45-46, may originate from different wavelengths. By means of splitting optics, for example, 51, this light can be split up into the different composing wavelengths, and in this manner a choice can be made which signals are most useful for sorting.

By using optical waveguide technology at the detection side of a sorting device, the detection unit can be made modular, and the alignment can take place in a more simple and more precise manner. This alignment moreover guarantees a more stable sorting quality in the time in respect to temperature and vibrations in comparison to a detection unit with free space optics.

Figure 10 also illustrates the third aspect of the invention.

In accordance with this third aspect, the supplied light 59, by means of a part, more particularly a partial bundle 60, is shone onto the product 3-3A, and the received light is received by this same entire bundle 40,

in this case by means of the aforementioned partial bundles 45-46-53 thereof, whereby preferably use is made of one and the same lens system 61 which serves for focussing the light 59 onto the products 3-3A, and at the same time also serves as an imaging system for the electromagnetic radiation transmitted, emitted and/or transformed by the products 3-3A.

Although figure 10 illustrates the third aspect of the invention in combination with the second aspect, it is obvious that, according to a variant, it is not necessary to provide in such combination. The third aspect, in other words, the fact that the supplied light and re-collected light takes place along one and the same waveguide and/or bundle of waveguides, can also be applied in embodiments where no selection based on the light dispersion is performed.

Also, the light does not have to be supplied through one partial bundle and to be collected by means of another parallel partial bundle of waveguides. Sending and re-collecting the light possibly also can take place by means of one and the same group of waveguides.

All waveguides and/or bundles may consist of optical fibers as well as of any kind of light-conducting channel.

The present invention is in no way limited to the forms of embodiment described as an example and represented in the figure, on the contrary may such sorting device be realized in different forms and dimensions without leaving the scope of the invention.

Moreover, it is noted that the invention, although it is described as a sorting device, also relates to the

methods applied therewith for realizing the sorting, in other words, the method providing for the alignment of light in a waveguide, the method that the waveguide is applied as a selection system, and the method that a waveguide or bundle of waveguides is applied for conducting the outgoing signal as well as the incoming signal.

Finally, attention is drawn to the fact that the terms "rejection unit" and "acceptable and unacceptable products" have to be interpreted in the broadest sense. Hereby, it is intended that the unacceptable products not necessarily consist of waste which is rejected. The sorting device according to the invention can also be applied to subject two or more useful products, or a single product with two or more qualities, to a selection.